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## **ABSTRACT**

This paper is concerned with the empirical relationship between government spending and private investment. A panel of 14 OECD countries is used. We present evidence which suggests the existence of a significant crowding-in effect of private investment by public investment, through the positive impact of infrastructure on private investment productivity. Moreover, government consumption appears to crowd out private investment. The implications of these results are of foremost importance when it comes to fiscal consolidation. Deficit reductions engineered through cuts in public investment could severely impinge upon private capital accumulation and growth prospects.



## 1. INTRODUCTION: FISCAL POLICY, GROWTH, AND CROWDING OUT

In this paper we investigate the relationship between private investment and government spending. Empirical evidence is brought to bear upon two closely related questions which lie at the core of the debate on the macroeconomic effects of fiscal policy: 1) Is public spending productive? 2) To what extent, if any, does government spending substitute for private investment?

The first question has stimulated a considerable amount of research since Robinson (1977) and Ram (1986) found a positive empirical relationship between government size and GDP growth. Although this association has also been obtained in more recent work (see Lin, 1994a), a number of papers have identified an inverse association between government spending and output growth (e.g. Grossman, 1988, Mallow, 1986, Peden and Bradley, 1989, and Grier and Tullock, 1989). In a careful and comprehensive analysis of this issue, Dowrick (1993) concludes that government size does not appear to have a systematic and significant effect on growth.

This literature has been criticized on three main grounds. First, as shown by Hsieh and Lai (1994) and Dowrick (1993), the sign of the association is quite sensitive to the choice of the sample of countries, the period under study, the econometric techniques and the existence of measurement problems. Second, as different categories of spending are well documented to have diverse economic effects, analyses ignoring this fact are not easy to interpret. Easterly and Rebelo (1993) and Lin (1994b), for example, show that spending categories that promote human or physical capital accumulation are positively associated with growth, while other spending items have negative or neutral effects. Finally, the single equation findings on the government -size/GDP- growth link could be invalid when this relationship runs through indirect channels, i.e. private investment.

These empirical shortcomings have a direct bearing on the second question. Since capital accumulation is the engine of output growth, any crowding-out effects of private investment by public spending impinge upon production expansion and welfare prospects. The bulk of the

empirical literature finds a significantly negative effect of public consumption on growth while the effects of public investment are found to be positive although less robust (Barro, 1991; Grier and Tullock, 1989; Easterly and Rebelo, 1993). To what extent can these results be traced to a crowding out of private investment? Aschauer (1989b) finds that the direct crowding-out effect of public investment is outweighed by a direct crowding-in effect associated with the role of public capital as a productive input and its complementarity<sup>(1)</sup> with private capital (see Aschauer, 1989a). The evidence gathered in Erenburg (1993), who estimates a simple macromodel with rational expectations, and in Erenburg and Wohar (1995), reinforces this conclusion, while the results in Bairam and Ward (1993) support the crowding-out hypothesis. As to the impact of government consumption, Aschauer (1989b) concludes that its crowding-out effect on private investment carries only a marginal explanatory power, a result that could be interpreted as an indication that public consumption is a close substitute for private consumption. However, recent evidence gathered by Karras (1994) forcefully suggests that private and government consumption are best described as complementary (or unrelated) goods<sup>(2)</sup>, a feature that reinforces the crowding-out effect of private investment.

The rest of the paper is organized as follows. Section II outlines the theoretical arguments behind the crowding-out hypothesis. For expositional purposes, we use a simple overlapping-generations model in which public and private capital are complements, whereas public and private consumption are independent. Section III evaluates the impact on private investment and private productivity of public spending. The empirical results obtained with a panel of 14 OECD countries are presented and briefly discussed. Finally, Section IV draws the main conclusions.

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<sup>(1)</sup> Public and private capital are "complementary" when the marginal productivity of the private capital increases as the quantity of public capital increases.

<sup>(2)</sup> If public consumption increases the marginal utility of private consumption, both are said to be "complementary", and viceversa.

## 2. PRIVATE INVESTMENT AND PUBLIC EXPENDITURE

The equilibrium approach developed in Aschauer (1988) and Aschauer and Greenwood (1985), among others, assumes a competitive economy populated by rational, identical, infinitely lived individuals. In this context, the general equilibrium relationship between public spending and private investment may be expressed in the following two equations:

$$i = i(f_k, i_g, c_g), \quad i_1 > 0, \quad i_2 < 0, \quad i_3 \leq 0 \quad (1)$$

$$f_k = f_k(k, k_g), \quad f_{k1} < 0, \quad f_{k2} \geq 0 \quad (2)$$

where  $i$  is private spending,  $f_k$  is the marginal product of capital,  $i_g$  and  $c_g$  are public investment and public consumption, respectively,  $k$  is private capital and  $k_g$  is public capital. Along neoclassical lines, changes in investment -which are described by the partial derivatives of the above functions- are the result of intertemporal smoothing of consumption by private agents.

Aschauer's discussion of the crowding-out issue is heuristic, due to the complexity of his analytic framework. Nonetheless, his qualitative conclusions carry over in much simpler neoclassical models. Suppose that our economy is populated by overlapping generations of equal size. Each household lives for two periods. Households earn labour income only in the first period. Labour supply is fixed. Consumption of a representative household when young in time  $t$  is:

$$c_t^1 = w_t - t_t - s_t, \quad (3)$$

whereas consumption when old at time  $t+1$  can be written as:

$$c_{t+1}^2 = s_t(1+r_{t+1}), \quad (4)$$

where  $w_t$  is the wage rate,  $s_t$  is savings,  $r_{t+1}$  is the interest rate in the second period and  $t_t$  is a tax levied on the young. The government uses tax revenues to finance public consumption of a public good nature -which



enters household's utility function- and public investment -which is a productive input in private production.

Suppose that the utility function of a representative agent is:

$$U = \delta \text{Lnc}_t^1 + (1-\delta) \text{Lnc}_{gt} + \frac{1}{1+\rho} \left[ \delta \text{Lnc}_{t+1}^2 + (1-\delta) \text{Lnc}_{gt+1} \right] \quad (5)$$

where  $c_g$  is public consumption,  $\delta$  represents relative preference for private consumption and  $\rho$  is the rate of time preference. Maximization of (5) subject to (3) and (4) yields the savings function:

$$s_t = \sigma(w_t - t_t), \quad \sigma = \frac{1}{2+\rho} . \quad (6)$$

For simplicity, assume that both private and public capital fully depreciate in every period. The production function in per worker terms is:

$$y_t = A i_t^\alpha i_{gt}^\beta, \quad \alpha + \beta < 1, \quad (7)$$

where  $i$  is private capital (and private investment) and  $i_g$  is public capital (and public investment). Competition in factor markets implies:

$$1+r_t = \alpha A i_t^{\alpha-1} i_{gt}^\beta = \alpha \frac{y_t}{i_t} \quad (8)$$

$$w_t = (1-\alpha) A i_t^\alpha i_{gt}^\beta = (1-\alpha) y_t . \quad (9)$$

Capital available for production in  $t+1$  equals savings of the young in  $t$ . This gives the momentary equilibrium condition:

$$i_{t+1} = \sigma(1-\alpha) A i_t^\alpha i_{gt}^\beta - \sigma t_t . \quad (10)$$

This equation, together with the government budget constraint: define the equilibrium of the economy.

$$t_t = c_{gt} + i_{gt} , \quad (11)$$

A permanent tax-financed increase in public consumption reduces both first-period private consumption and savings, and thus investment in the next period. In the long-run, after dropping time subscripts, we obtain:

$$\frac{di}{dc_g} = - \frac{\sigma}{1 - \sigma\alpha(1-\alpha)Ai^{\alpha-1}i_g^\beta} < 0 , \quad (12)$$

provided that the economy is not too far away from the golden rule (note that when  $r=0$ , by equation 8 the denominator in 12 reduces to  $1-\sigma(1-\alpha)$ ). As this crowding-out effect generated by public consumption is associated with the effect of taxes upon savings, a tax-financed increase in public investment must also produce a direct crowding-out effect of private investment. However, public investment may have an additional effect: private investment is crowded-in whenever public capital raises the productivity of private capital. In fact, if the initial level of public capital were well below its optimal (i.e. output-maximizing) level, the crowding-in effect would outweigh the negative influence of taxes upon savings. More generally, the steady-state effect of an increase in public investment upon private capital accumulation is:

$$\frac{di}{di_g} = - \frac{\sigma[1-\beta(1-\alpha)Ai_g^{\alpha}i_g^{\beta-1}]}{1-\sigma\alpha(1-\alpha)Ai^{\alpha-1}i_g^\beta} \begin{matrix} < 0 \\ > 0 \end{matrix} \quad (13)$$

In the more elaborate Aschauer model this ambiguity emerges as well. The differences are just a matter of detail. When public and private capital are equally productive, an increase in public investment crowds out an equivalent amount of private investment, with no effects upon wealth and consumption. However, an additional crowding-out effect would arise if public investment were more productive: as lifetime wealth increases so does consumption today. These two short-run effects could be compensated by the crowding-in effect which operates through an increase in private capital productivity. As to the consequences of an increase in public consumption, Aschauer admits the possibility that its effect could be nil. If public consumption is a perfect substitute for

private consumption or the marginal propensity to consume out of wealth remains constant over time for every agent, private investment changes would not be needed to smooth out consumption. None of these assumptions are made in our simple expositional model<sup>(3)</sup>.

### 3. DATA, METHODOLOGY AND EMPIRICAL RESULTS

The empirical analysis is carried out using the annual time-series-cross-section data from Summers and Heston (1991). Only the fourteen OECD countries with available data on infrastructure capital were included for the period 1979-88<sup>(4)</sup>, which resulted in an unbalanced panel data set. Data definitions are given in the Appendix.

Our analysis of the crowding-out hypothesis is based on the estimation of the following pair of equations:

$$i_{jt} = a_{1jt} + a_{2jt} f_{kjt} + a_{3jt} i_{gjt} + a_{4jt} c_{gjt} + e_{1jt} \quad (14)$$

$$\ln f_{kjt} = b_{1jt} + b_{2jt} \ln k_{jt} + b_{3jt} \ln k_{gjt} + e_{2jt} \quad (15)$$

where subscripts  $t$  refer to time and  $j$  to country,  $i$  and  $i_g$  are, respectively, private and public investment in relation to private productive capital stock (private and public investment rates),  $c_g$  is public consumption, in relation to private productive capital stock,  $f_k$  is

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<sup>(3)</sup> These models are not directly comparable. Note that we are assuming that public and private consumption are neither complementary nor substitutes. On the other hand, with income accruing only in the first period and a fixed propensity to save, crowding out obtains even if the marginal propensity to consume remains constant. In such case, which implies  $r = \rho$ , private investment is crowded-out by  $[1 - a(1 - \rho)]^{-1}$  units per unit of additional government consumption spending.

<sup>(4)</sup> The countries and the periods are the following ones: Australia (1979-87), Austria (1979-87), Belgium (1979-87), Canada (1979-88), Denmark (1979-88), Federal Republic of Germany (1979-88), Finland (1979-87), France (1979-88), Ireland (1979-87), Norway (1980-86), Spain (1979-86), Sweden (1979-87), United Kingdom (1979-87) and United States (1980-87).

marginal private capital productivity (which is proxied by the ratio of gross operating surplus to private productive capital stock),  $k$  is the stock of private productive capital and  $k_g$  is infrastructure capital, so that no residential investment is involved<sup>(5)</sup>. We would expect  $a_2$  to be positive, and both  $a_3$  and  $a_4$  to be non-positive under the crowding-out hypothesis. On the other hand, given the standard assumption of decreasing marginal productivity,  $b_2$  is expected to be negative, and  $b_3$  positive if infrastructures and private productive capital are complements.

The econometric analysis of the crowding-out issue requires the use of techniques well suited to deal with country heterogeneity. Let us first refer to the most restrictive version of (14) and (15). Assume that  $a_{mjt} = a_m$  and  $b_{mjt} = b_m$ ,  $\forall j, \forall t$ : that is, the response of private investment and private capital productivity to the right-hand side variables does not change over time nor across countries. The results of such a restrictive model are presented in column (1) of Table 1. In columns (2) to (6) we relax these restrictions so as to take into account the heterogeneity of the data. In column (2) we report the results of letting  $a_1$  and  $b_1$  change across countries while taking the remaining coefficients to be the same across countries. The estimates correspond to a fixed effects model with country dummies, and are therefore a within estimate. The dummy coefficients are not reported. In order to choose between the most restrictive model and the within estimates, an F test is carried out, whose results are reported in the lines headed by  $F^{(6)}$ . In column (3) we

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<sup>(5)</sup> Unfortunately, our data do not allow private and public infrastructure to be separated out. It may be argued that both types of infrastructure should have roughly the same effects on productivity. In any case, this fact has to be borne in mind when interpreting the results.

<sup>(6)</sup> This test is formulated as:

$$\frac{SSRR - SSRU/(ku - kr)}{SSRU/(T - ku)} \sim F_{(ku - kr), (T - ku)}$$

where U and R stand for the unrestricted and the restricted model, respectively, SSR is the sum of squared residuals,  $k$  is the number of estimated coefficients and  $T$  is the total number of observations.

TABLE 1. CROWDING-OUT EFFECT (1979-1988)									
		Fixed effects				Random effects			
		(2)	(3) (a)	(4)	(5)	(6)			
eq (1)		$i_{jt} = a_{1jt} + a_{2jt} f_{kjt} + a_{3jt} i_{gjt} + a_{4jt} c_{gjt} + e_{1jt}$							
eq (2)		$\ln f_{kjt} = b_{1jt} + b_{2jt} \ln (k/l)_{jt} + b_{3jt} (k_g/l)_{jt} + e_{2jt}$							
Restricted		(1)	(2)	(3) (a)	(4)	(5)	(6)		
eq (1)	$f_{kjt}$	0.38 (11.53)**	0.38 (4.03)**	0.61** (6.57)**	0.37 (6.18)**	0.33 (6.00)**	0.37 (6.08)**		
	$i_{gjt}$	-0.71** (2.46)	-0.31 (0.75)	-0.16 (0.34)	-0.20 (1.52)	-0.63 (1.83)*	-		
	$c_{gjt}$	-0.16 (2.54)**	-0.54 (1.55)	-1.94** (4.12)	-0.52 (1.51)	-	-0.25 (1.86)*		
eq (2)	$\ln(k/l)_{jt}$	-0.83 (16.70)**	-0.49 (3.96)**	-0.69 (2.95)**	-0.45 (5.47)**				
	$\ln(k_g/l)_{jt}$	0.24* (10.88)**	0.72 (4.72)**	0.47 (1.74)*	0.37 (5.01)**				
σ	eq (1)	0.036	0.023	0.018	0.025	0.025	0.025		
	eq (2)	0.139	0.045	0.039	0.052				
F	eq (1)		13.69** [13,109]	-	-	14.50** [13,110]	14.81** [13,110]		
	eq (2)		81.76** [13,110]	-	-				
χ²	eq (1)		1.26 [3]	-	-	0.20 [2]	1.83 [2]		
	eq (2)		23.64** [2]	-	-				
t x j		126	126	112	126	126	126		

σ is the standard error of the regression, F is a F test of the fixed effects model versus the most restricted one, χ² is a Hausman test of the fixed versus the random effects model.

\*\* Significant contrast at a 5% level; \* significant contrast at a 10% level. In square brackets, degrees of freedom for the F and the Hausman tests.

(a): OLS estimates in first differences.

report the estimates of the model in first differences. Such an approach not only takes into account fixed effects, which drop out when the model is specified in first differences, but may be regarded as a way of dealing with non-stationarity when this problem is present. Column (4) reports the results obtained from a random effects model. The main difference with the within estimator is that the country specific effects are now treated as random and uncorrelated with the regressors. A Hausman test is constructed to check for this restriction, with the results shown in the row labeled  $\chi^2$  in table 1<sup>(7)</sup>.

As far as the first equation is concerned, the signs of the coefficients are the expected ones under the different estimated models. The F test does not allow to accept the restricted model to be accepted when the alternative includes country-fixed effects and, on the other hand, the random effects model cannot be rejected when the alternative is the country-fixed effects model. Therefore, the results in columns (1) and (2) can be disregarded as far as the first equation is concerned. The evidence in column (3) implies a negative impact of both public consumption and investment on private investment, although only the public consumption coefficient is statistically significant. When the results in column (4) are analyzed, it appears that the impact of public investment on private investment is negative, but not statistically significant. The same result applies to public consumption.

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<sup>(7)</sup> The Hausman test is formulated as:

$$H = (\hat{\beta}_w - \hat{\beta}_{GLS})' (\hat{V}_w - \hat{V}_{GLS})^{-1} (\hat{\beta}_w - \hat{\beta}_{GLS})$$

where  $\hat{\beta}_w$  is the vector of the k within-group estimates,  $\hat{\beta}_{GLS}$  is the corresponding generalized least squares estimate of the random effects model, and  $\hat{V}_w$  and  $\hat{V}_{GLS}$  are their respective estimated variance-covariance matrices. Under the null hypothesis of no correlation (the random effects model), it is the case that:

$$\text{plim } (\hat{\beta}_w - \hat{\beta}_{GLS}) = 0$$

$N \rightarrow \infty$

and H is distributed as a  $\chi^2$  with k degrees of freedom (excluding intercepts).

The lack of significance of both public sector investment and government consumption in the investment equation (equation 14) under the random effects model might arise from collinearity between these two variables. If this were the case, dropping one variable would increase the statistical significance of the other. Columns (5) and (6) report the results of the estimation of equation (14) under a random effects model, when  $a_2$  or  $a_3$  are restricted to zero. It should be noted that the Hausman test does not reject the null hypothesis of non-correlation between the country effects and the observable variables, i.e. the random effects model is not rejected by the data. While the value of the coefficient of marginal private capital productivity is quite stable across specifications, the estimated coefficients for public investment and public consumption do not show such robustness. In fact, the new estimates seem to indicate that public investment has a marginally significant direct impact on private investment while public consumption also has a negative but small impact. Therefore, both public consumption and public investment, appear to crowd out private investment, although the statistical significance of these results is rather weak. Note finally that, under the specification in first differences (column 3) -a valid reference in the presence of non-stationarity in the data- only consumption spending has a significantly negative effect on private investment. All in all, our evidence does not uncover any significant crowding-out effects associated with public investment when productivity is held constant, while results on the negative effects of public consumption on private investment are mixed.

With regard to the productivity equation (equation 15), it is also the case that the signs obtained under the four specifications are the expected ones. The constant returns to scale restriction was imposed after a preliminary test of its validity<sup>(8)</sup>. While the F test rejects the restricted specification in column (1) in favour of the fixed effects model, the Hausman test rejects the null hypothesis of absence of correlation between the country effects and the regressors. Thus, the within estimates in column (2) appear to be the most appropriate on statistical

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<sup>(8)</sup> When a test of this restriction was carried out, the result was that under the country fixed effects model it cannot be rejected.

grounds. The negative effect of private capital reflects the decreasing marginal productivity. The results strongly suggest a positive effect of infrastructures on private productivity, so that it may be argued that public investment accumulated in the past appears to enhance productivity. The estimates in column (3), with the model in first differences, lead to the same conclusions, although the infrastructure variable becomes less significant. Therefore, the results suggest that there is an indirect crowding-in effect through the positive impact of public infrastructures on private productivity.

Besides the possibility of the series not being stationary, so that the results in levels could be a reflection of a spurious relationship, endogeneity may be present: it would arise from the relationship between private investment and private capital, a case in which OLS would provide inefficient estimates. The first limitation has already been tackled through the estimation of both equations in first differences (column 3 in Table 1). In order to deal with the endogeneity issue we can use instrumental variable techniques. The estimates of this latter specification (provided in Table A1 of the Appendix) produce very similar qualitative results. Public consumption appears to have a significantly negative impact on private investment. On the other hand, the role of public investment is clarified: its coefficient keeps the expected negative sign but does not appear to be significant, both when public consumption and investment are jointly taken into account, as well as in the case where public consumption is not included in the regression. Thus evidence in favour of a direct crowding out associated with public investment is weak. With regard to the second equation, infrastructure has a positive impact on productivity, in line with the results reached when no simultaneity considerations were involved<sup>(9)</sup>.

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<sup>(9)</sup> As a means of testing the specification of the productivity equation, a direct estimation of a production function is discussed in the Appendix. It provides additional evidence on the technology of the countries under study, and on the productive role of infrastructures. The results presented in Table A2 of the Appendix show again that there is a crowding-in effect of public investment through its positive impact on private sector productivity. Such a result reinforces those obtained through the estimation of a productivity function with productivity proxied by the ratio of gross operating surplus to private productive capital.



#### 4. CONCLUSIONS

This paper has investigated the relationship between private investment and public spending. The paper has aimed to test the presence of private investment crowding out by current expenditure (public consumption) and capital expenditure (public investment), with an unbalanced panel data set for 14 industrialized countries for the period 1979 to 1987.

The empirical results presented in the paper lend support to the existence of a crowding-in effect of private investment by public investment, through the positive impact of infrastructure on private investment productivity. Moreover, there is little or no evidence of direct crowding out of private investment by public investment when productivity is held constant, while there is some evidence of crowding out by public consumption.

Given the data limitations, we need to be cautious about applying these results to particular instances. It is quite possible that specific types of government consumption may help GDP growth, and the opposite might be true for some public investment projects. On the other hand, the analysis presented in the paper does not deny that particular ways of funding public spending may exert their own influence upon investment.

All in all, our findings stress the need to distinguish carefully between current and capital expenditure when evaluating the impact of fiscal policy on private investment and output growth. From a policy view, the implications of the evidence are of foremost importance when it comes to fiscal consolidation. Public deficit reductions that rely mainly on public investment cuts could severely impinge upon private investment and growth prospects.

## APPENDIX

### A. DATA SOURCES AND DEFINITIONS

The source of the variables is the Summers and Heston (1991) database PWT5. The periods and countries have been chosen by a data availability criteria, so that all the countries with data on public and private infrastructure have been included. Although we are interested in having a public capital variable, the Summers and Heston database does not provide a separation between public and private infrastructure. It may be argued that public and private infrastructure should have roughly the same effects on productivity. To the extent that public investment increases the stock of infrastructure capital, the crowding-out issue can be discussed along the lines suggested by the theoretical literature.

Variable definitions:

a) Private investment:

$$i = I \cdot \text{RGDPW} \cdot \text{IPRI} / (\text{Kdur} \cdot \text{Kapw})$$

b) Public investment

$$i_g = I \cdot \text{RGDPW} (1 - \text{IPRI}) / (\text{Kdur} \cdot \text{Kapw})$$

c) Capital productivity

$$f_k = (1 - \alpha) \cdot \text{RGDPW} / (\text{Kdur} \cdot \text{Kapw})$$

d) Public consumption

$$c_g = G \cdot \text{RDGPW} / (\text{Kdur} \cdot \text{Kapw})$$

e) Private productive capital per capita

$$k = (\text{Kdur} + \text{Knres}) \cdot \text{Kapw}$$

f) Public and private infrastructure per capita

$$k_g = K_{other} \cdot Kapw$$

g) Production per worker

$$\frac{y}{l} = RGDPW$$

where all the variables are expressed at constant international prices and

I:	Total investment over GDP (1985 int. prices).
RGDPW:	Real GDP per worker (1985 int. prices).
IPRI:	Gross domestic private investment share in total investment.
Kdur:	Producer durables (% of Kapw).
Kapw:	Capital stock per worker (1985 int. prices).
Kother:	Other construction (% of Kapw).
Knres:	Nonresidential construction (% of Kapw).
G:	Public consumption share in GDP.
$\alpha$ :	Share of wages participation in GDP, calculated as the ratio of compensation of employees over GDP in every year of the sample (OECD data)

## B. INSTRUMENTAL VARIABLES ESTIMATES

TABLE A1. CROWDING-OUT EFFECTS				
INSTRUMENTAL VARIABLE ESTIMATION				
(1979-88)				
		(1)	(2)	(3)
eq (1)	$f_{kjt}$	0.80 (4.92)**	0.74 (4.68)**	0.80 (5.00)**
	$i_{gjt}$	-0.07 (0.13)	-0.62 (1.36)	-
	$c_{gjt}$	-1.02 (2.28)**	-	-1.05 (2.66)**
eq (2)	$\ln(k/l)_{jt}$	-0.56 (4.06)**		
	$\ln(k_g/l)_{jt}$	1.07 (6.29)**		
$\sigma$	eq (1)	0.024	0.024	0.024
	eq (2)	0.041		
t x j		112	112	112

$\sigma$ : standard error of the regression

The instruments used are  $f_{kt-1}$ ,  $c_{gt-1}$  and  $i_{gt}$  in equation (1) and  $\ln(k/l)_{t-1}$  and  $\ln(k_g/l)_t$  in equation (2). Country dummies were included in both equations as instruments.

### C. PRODUCTION FUNCTION EQUATION

The estimated equation is given by

$$\ln (y/l) = a + (1-\alpha-\beta) \ln[k/l] + \beta \ln[k_g/l]$$

where

$$y = a l^a k_g^\beta k^{1-\alpha-\beta}$$

so that again the restriction of constant returns to scale has been imposed<sup>(10)</sup>. The results are presented in table A2. The inclusion of a time trend,  $t$ , aiming at capturing technological change, results in the estimates shown in columns (2), (4), and (6). The random effects model seems to be the one that fits better the data. The positive and statistically significant sign of the infrastructure variable seems to be present in all models, except under column (4). However, in that case, the trend variable is not statistically significant either, so that the specification seems to be rejected by the data.

The fact that the random effects model cannot be rejected statistically may be a reflection of the fact that the technological heterogeneity among the different countries is not directly related to the different initial states of the technology. In fact, it could be identical for all countries, and the individual effects could be related to other aspects of the economic environment.

Looking at columns (5) and (6) it may be concluded that, although the output elasticity with respect to infrastructure is smaller than the elasticity with respect to private capital, the results imply again that there is crowding in of public investment, through its positive impact on private productivity. This result reinforces those presented in Table 1.

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<sup>(10)</sup> The tests of the hypothesis of constant returns to scale are not completely satisfactory, even when the within estimator is considered. However, given the specification of the productivity function it seems more reasonable to have constant returns to scale.

TABLE A2. PRODUCTION FUNCTION WITH INFRASTRUCTURE CAPITAL						
	Restricted		Fixed effects model		Random effects model	
	(1)	(2)	(3)	(4)	(5)	(6)
$\ln (k/l)_{jt}$	0.19 (3.60)**	0.17 (3.23)**	0.53 (6.45)**	0.48 (4.47)**	0.49 (7.45)**	0.38 (4.34)**
$\ln (k_g/l)_{jt}$	0.19 (5.94)**	0.19 (5.94)**	0.21 (2.09)**	0.16 (1.27)	0.20 (2.95)**	0.15 (2.08)**
t		0.009 (1.77)*		0.002 (1.27)		0.003 (1.87)*
$\sigma$	0.149	0.148	0.030	0.030	0.033	0.032
F			218.11**[13,118]	211.72**[13,117]		
$\chi^2$			5.16 [2]	6.87 [3]		
t x j	126	126	126	126	126	126

\*\* Significant at a 5% level; \* significant at a 10% level. In square brackets, degrees of freedom for the F and the Hausman tests.



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